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THE BLACK ROT OF THE CABBAGE.

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U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY,
Washington, D. C., December 16, 1897.

SIR: I have the honor to transmit herewith an article on "The Black Rot of the Cabbage," by Dr. Erwin F. Smith, an assistant in this division, and respectfully recommend that it be published as a Farmers' Bulletin. The main object of the article is to give cabbage growers the benefit of some recent discoveries in this office of remedies for preventing the disease; and the dissemination of the information, it is believed, will result in the saving of many thousands of dollars annually.

Respectfully,

ALBERT F. WOODS,
Acting Chief of Division.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE BLACK ROT OF THE CABBAGE.

INTRODUCTION.

This disease is known to the growers of cabbages in various parts of the country under several different names, the commonest of which perhaps are "stem rot" and "black rot." It has been described technically by the writer under the title "*Pseudomonas campestris* (Pammel): The Cause of a Brown Rot in Cruciferous Plants."[1] Although this disease has come into prominence only within the last few years, it is now a serious hindrance to cabbage growing in several States.

The following pages have been prepared, not as a final word on the subject of treatment, but rather to give the cabbage growers the results of some recent discoveries which, while not as fully worked out as one could wish, still appear to have great practical value in the prevention and control of this malady. An attempt will be made to show the grower where the danger lies, how the introduction of the disease may often be prevented, and how, when already introduced, great losses may sometimes be avoided. No way is known of curing the disease or of entirely ridding a locality of it when once well established. The present methods of growing the crop being chiefly responsible for the introduction and spread of the rot, the whole subject of treatment may be summed up in one word—PREVENTION.

NATURE AND PREVALENCE OF THE DISEASE.

LEADING SYMPTOMS.

This disease may appear in the plant at any stage of growth, and is characterized by the following symptoms: Dwarfing, or one-sided growth of the heads, or, if the disease is very severe and has begun early in the season, by the entire absence of any heads, and in extreme cases by the death of the plant. Occasionally the heads rot and fall off, but this is not a necessary consequence, the soft, bad-smelling rot being due to the entrance of other organisms. If the stumps of affected plants are broken or cut across a brown or black ring will be observed, corresponding to the woody part of the stem, this being the

[1] Centralblatt für Bakteriologie, Parasitenkunde, und Infektionskrankheiten, 2 Abt., Bd. III, pp. 284, 408, 478, Pl. I.

part of the stem specially subject to the disease. In bad cases this blackening may be easily traced upward into the center of the head, and is generally worse on one side.

In the leaves the symptoms usually begin at the margins, and consist in yellowing of all the affected parts except the veins, which become decidedly brown or black. The leaves appear to have "burnt edges." From the margin of the leaf the progress of the disease is inward and downward toward the stem. It usually enters the latter through the leaves. Subsequently the disease passes out again from the infected stem into healthy leaves and up into the center of the head. If leaves diseased at the edges are pulled off and examined where they join the stem, the groups of fibrovascular bundles, or leaf traces, in the petiole are seen to be either free from the disease, in the early stage, or decidedly brown or even deep black from its presence. Leaves attacked in this manner fall off prematurely one after another, leaving in bad cases a more or less elongated stem covered with leaf scars and crowned with a tuft of small leaves. If the disease has entered the stem only on one side, that side is dwarfed and the head becomes one-sided.

CAUSE AND MANNER OF INFECTION.

The cause of this disease is a yellow bacterium, which enters the plant above ground and usually at the margin of the leaves through small openings, known as water pores, scattered over the teeth of the leaf. The plants are also sometimes infected as the result of bites of insects, the disease spreading in the leaf in all directions from the bitten places. As yet there is no evidence whatever that the organism can enter the plant through the root-system. At least nine-tenths of the infections are through the water pores.

This discovery was made by the writer in the winter of 1896–97 during the course of greenhouse experimentation with the germ. In the summer of 1897 an extensive study of the disease in the field served to confirm and extend the previous observations, leaving no doubt whatever that this is the common method of infection. In one instance 411 separate leaf infections by way of water pores were counted on a single cabbage plant (Flat Dutch), while from 50 to 150 separate infections by way of the water pores were seen very often on cabbage plants in widely separated localities, i. e., in Michigan, Wisconsin, Ohio, and New York. The entrance into the leaf of the germs which have lodged over the water pores is rendered possible by the fact that during cool nights or in damp weather the cabbage plant exudes moisture in the form of drops, and these drops remain over the water pores on the margin of the leaf long enough for the bacteria accidentally lodged there to multiply and swim into the interior of the leaf through the openings. In just what way the organisms become lodged over these openings is not known. It is probable, however, that they commonly find their way to such positions from the earth along with minute par-

ticles of dust or are carried from diseased to healthy plants or from diseased leaves to healthy leaves of the same plant on the bodies of insects. It seems likely that the direct propagation of the disease by insects—that is, through bites—is by no means the chief injury done by them. They frequently gnaw diseased parts of the plant, breaking open and coming into intimate contact with tissues containing myriads of the germs, and even if they do not again bite or puncture the plant they crawl over portions, which they certainly contaminate by leaving the germs scattered about. Infection is then only a question of whether the germs are left in the right place, i. e., over the water pores, as a certain number of them are sure to be.

Infections by means of the gnawings of insects were obtained by the writer in the greenhouse, under strict control conditions, in the spring of 1897. Similar infections were frequently observed in the field in August and September of that year—that is, small bitten places, uniformly encircled by gradually enlarging areas of yellow and black-veined tissue, drying out in the center, and surrounded by a more recently affected and nearly healthy border, and a little farther away by entirely sound tissue, the diseased parts being uniformly occupied by the bacteria.

DISEASE AFFECTS OTHER CULTIVATED PLANTS.

This disease is not confined to the cabbage, but attacks a number of species belonging to the mustard family (Cruciferæ). It is not known to occur outside of this family. It has been found on various kinds of turnips, causing a brown internal rot, which frequently leaves a cavity and often prevents the formation of any bottom. The writer has also seen the disease in cauliflowers from Clyde, Ohio, and Floral Park, Long Island, and has successfully inoculated it into cauliflower, kale, and rape. It is one disease in all of these plants, i. e., due to the same germ.[1] Whether or not it is also identical with the Japanese bacterial disease on radishes is not yet known. In his inoculation experiments the writer was unable to communicate it very readily to radishes.

OCCURRENCE OF THE DISEASE IN WEEDS.

The disease has been successfully inoculated into the black mustard (*Brassica nigra*) in greenhouse experiments, and was found in the summer of 1897 to be very common in charlock, or wild mustard (*Brassica sinapistrum*), in the cabbage fields south of Racine, Wis. Fully 100,000 cases were noted in the mustard plants of a single field. These plants were growing promiscuously with badly affected cabbages, from which they appeared to have contracted the disease rather than the opposite. In most cases the infection began at the edges of the leaves. The dis-

[1] For proof of many of the statements made in this bulletin the reader is referred to the technical paper cited on page 5.

ease had, however, been found previously in the same weed growing around a mud puddle by the roadside some miles northwest of Racine and remote from any cabbage field, so that it is not impossible that it is native to this weed.

The symptoms in the charlock were quite like those in the cultivated cruciferous plants, i. e., a wilting and yellowing of the foliage, with more or less browning of the veins and a decided browning of the woody part of the stem, the vessels of which were crowded full of the bacteria. Sometimes the yellow color of the germs could be seen in the ooze from the cut stems. Cultures were made from the interior of such stems and a yellow organism obtained which proved to be identical with the cabbage germ—that is, behaved the same way in various culture media and produced the disease when inoculated into cabbage plants.

FIELD STUDIES IN 1897.

This disease was studied in the field for the first time by the writer in the year 1897. About two months was devoted to the subject, the time being divided between the following places: Saginaw, Mich.; Racine, Wis.; Clyde, Ohio; Rochester, N. Y., and Washington, D. C. In all these localities it has obtained a strong foothold and has already done serious damage. Some fields in each of these places were found to be nearly or quite ruined, while others were only slightly affected, and still others were entirely free. Diseased cabbages were frequently seen on the Washington market in October and November, 1897. These came from Maryland, Virginia, and New York. One carload in particular from western New York was badly affected and of little value.

EXTENT OF LOSSES.

The damage at Racine during the last three years probably exceeds $100,000. Some of the cabbage fields at Green Bay, Wis., have also been seriously injured. The loss at Saginaw has been less, but has already aggregated several thousand dollars. The disease was serious in quite a number of fields at Clyde, Ohio, in 1896, and again this year. The yield in one field of 11 acres was reduced in 1897 about two-thirds, while that of several others seen by the writer was cut about one-fourth to one-third. Around Rochester the disease has gained quite a foothold, e. g., at Mumford, Avon, West Rush, etc., and the losses in 1896 and 1897 aggregated many thousand dollars. The disease is also reported to be very serious at Rosehill, Ill., and in some other places, so that the acreage of cabbage is much less than it was formerly. An extensive grower of cabbages on Long Island writes: "The growers are now cutting [December 10, 1897], and it is safe to say not one plant in two is free from the disease. If this continues the industry will soon be ruined, which will be a great loss to this section of our country."

HOW LONG PRESENT IN THIS COUNTRY.

The disease has been present at Racine for at least a dozen years, but has come into prominent notice only within the last three or four years. At Saginaw it did not attract general attention until 1896. At Clyde it has been serious for only two or three years, and the same is true of places around Rochester. How long it has been present in the vicinity of Washington is not known, but apparently at least a dozen years if statements of growers are to be credited. Cabbage growing on a large scale is of recent origin in most of these places, and the disease has sprung into importance along with the development of the new industry.

GEOGRAPHICAL DISTRIBUTION.

The distribution of this parasite is not known very precisely. It is probable that the disease occurs in all the eastern United States and that it is not a recent source of loss, but one of long standing. In addition to the above-named places where it has been studied on the ground by the writer diseased material has been received from eastern Pennsylvania, from Baltimore, and from Long Island. It has also been reported on good authority from several other States. At the present writing, therefore, it is known to occur in fifteen or sixteen States, as follows: Alabama, Kentucky, Iowa, Nebraska, Illinois, Indiana, Ohio, Minnesota, Wisconsin (several places), Michigan (several places), New York (several places), Pennsylvania, New Jersey, Maryland (several places), Virginia, and Florida (?).

SOURCES OF INFECTION.

CONFLICTING STATEMENTS RESPECTING ORIGIN.

The statements of cabbage growers respecting this disease are contradictory, and it would be impossible, from such statements, to reason out any satisfactory explanation for its appearance or nonappearance in any given field. When, however, the disease is studied on the ground many of its so-called vagaries are seen to be simply misinterpretations or misunderstandings of what has been seen or done, and certain facts relative to its distribution and spread become very plain. From such field study, therefore, in connection with the laboratory and greenhouse studies already made, it seems possible to deduce certain helpful suggestions as to methods of coping with the disease. These will be given in the following pages, subject, of course, to revision, as additional exact knowledge is gained respecting the habits of the parasite.

SUPPOSED INTRODUCTION ON SEED.

Growers of cabbages have been quite prone to ascribe the disease to bad seed, but up to this date no one has shown conclusively that any outbreak of the rot has resulted from germs introduced in this way. It

does not follow, of course, that this may not finally be shown to be one of the ways for its dissemination, but it is quite time to sound the note of warning when the danger is definitely discovered. Seedsmen have some rights as well as buyers of seeds, and their business ought not to be injured on the strength of mere surmises. On the other hand, growers of cabbage seed would do well to destroy, as promptly as possible, all seed plants showing any traces of this disease, and certainly the seed from such plants should never be gathered.

POSSIBLE SPREAD BY WAY OF THE MANURE PILE.

At Saginaw, Mich., a large manure heap was seen composting for use on a cabbage field in 1898. Lying on this heap was a great deal of cabbage refuse—stems, bad heads, etc.—and a very little search showed that a considerable number of these stems were blackened in the woody part as a result of this disease, and it seems not at all unlikely that the organism may winter over in a manure pile and thus find its way to the fields the following spring. If such be the case, we have therein a ready explanation of what some growers have observed, namely, the occasional perplexing appearance of the disease on fields planted to cabbages for the first time.

In Michigan the writer saw a field quite free from the disease excepting a relatively small portion (an acre or two) which contained a good many cases. On inquiry it turned out that this part of the field coincided with an area which had been covered with the rotten cabbages and other refuse taken out of the cabbage storehouse.

TRANSMISSION BY ANIMALS.

This disease may also be disseminated by insects and by mollusks (slugs), especially to all parts of the head and to neighboring plants of the same field.

CONTAMINATED SOILS.

Undoubtedly, as will be made clear by what follows, a contaminated soil is the most frequent source of plant infection, and seedling plants infected from such soil are the most common means of seeding down or colonizing the germ in fields previously free from it. In other words, man is himself the principal agent in the dissemination of this disease.

FUNDAMENTAL PROBLEMS.

IS ONE VARIETY MORE SUBJECT THAN ANOTHER?

It is generally believed among growers, or quite commonly believed, at least, that some varieties of cabbage are much more susceptible than others. This appears to be reasonable enough, but seems to the writer to lack support in the way of exact and sufficient evidence, especially since there is no uniformity of agreement as to which varieties are most

subject. In matters of this kind people are very apt to jump to conclusions, e. g., if a man had two varieties of cabbage, one planted on infected land and the other on land free from the germ, and the plants on the infected land became diseased while the others remained healthy, he, not knowing very much about the cause of the trouble, would almost certainly declare one variety more subject to the disease than the other. That much of the prejudice against certain varieties rests only on this sort of evidence admits of no doubt whatever. This caution, however, is not to be construed as a denial of varietal susceptibility, but only as a request for suspension of judgment until good evidence in support of it has been produced.

Two types of cabbage are commonly cultivated in the districts where the writer has studied this disease, namely, large-headed, rather loose sorts, grown for autumn use and the manufacture of sauerkraut, and smaller sorts, with very compact heads, grown for winter use and to supply the spring demand. These latter kinds are generally known as Holland or Danish cabbage, and the seed is often imported. In many cases (not all) it is these varieties which, it has been asserted, are most susceptible to the disease, and the seedsmen selling seeds of these imported kinds have been accused of introducing the disease. So far as yet known this disease does not occur in the cabbage fields of the Netherlands or Denmark, or in any other part of the Old World, but possibly, now that it has been described and figured, we may hear of its occurrence in Europe.

The writer made some observations in the field this summer which lead him to think that the so-called susceptibility of varieties is largely a matter of having planted the given variety on infected soil. At any rate much more extensive and careful field studies must be had before anything like exact and trustworthy statements can be made respecting the susceptibility of any given variety. The same variety (Danish Ballhead) has been seen badly diseased on one farm and healthy on another, the seed for the two fields having been procured from the same seedsman. Fields of the following varieties were observed to be badly diseased: Danish Ballhead, All Seasons, Flat Dutch, Burpee's Safe Crop, and Holland. Other fields, however, in the same regions and planted to these same varieties were found to be free from the disease.

DOES THE PARASITE LIVE OVER WINTER IN THE SOIL?

Although the writer has made no attempt to determine by means of cultures whether or not the organism lives over winter in the soil, yet the fact that it does seems to be placed beyond reasonable doubt by the results which he has obtained from field studies; so that it is safe to predict that whoever searches carefully for it in the soil of diseased fields the following spring will be sure to find it sooner or later in a certain per cent of the samples of soil. This is not denying, of course, that it may die out of some fields or parts of fields or be crowded out

by antagonistic organisms while retaining a foothold in other places. Simple winter cold may not be expected to kill it, since freezing has little effect on bacteria in general.

In many instances where cabbages have been planted on new land no disease has appeared, while on the same farms, when the cabbages were planted on land that had been in cabbages the previous year or for several years in succession, the disease has appeared. In one instance in Wisconsin a field of several acres was found to be diseased from one end to the other. The owner and the writer estimated the number of affected plants at 80 to 90 per cent. This field was in cabbages in 1895 and there were some cases of the disease present. It was again planted in 1896 and there were many cases of the disease. The infections of 1897 seemed to be due to germs which wintered over in the soil, because another cabbage field on the same farm and set from the same seed beds, but planted on sod land, was almost entirely exempt.

A similar case was observed in another locality in the same State. A field of 6 or 8 acres was studied quite carefully, owing to the irregular distribution of the disease. On one side of the field there were a great many cases, whereas in the middle and on the other side there were very few. The topography and soil of the field were quite uniform, the plants all came from one seed bed and were healthy when set out, and the difference in the amount of disease in the field appeared to be clearly traceable to conditions prevailing the preceding year, that part of the field which was badly diseased being planted on land which was in cabbages in 1896 and on which the disease had been very bad. The portion of the field which was practically free from the rot was planted on sod ground, plowed up for the purpose. The seed bed was on this side of the field in sod ground, and although many thousands of plants remained no diseased ones could be found. Similar cases were observed in other places, e. g., in Ohio and New York, leaving no doubt in the mind of the writer that the parasite is capable at least of wintering over in the field. Whether it always does so is quite another question. No case, however, was observed or reported to the writer of any dying out of this disease after being once prevalent in a field.

SUGGESTIONS FOR PREVENTION.

EARLY vs. LATE PLANTING.

The writer has seldom found this disease in the roots of late-sown turnips, even when growing on infected soil, and there also seems to be some reason for thinking that the late-planted cabbages are less subject to it than those which are planted early. Additional observations, however, are necessary to fully establish this conclusion. Very likely also the results of one year might contradict those of another year, and such would almost certainly be the case if a cool, dry summer were fol-

lowed by a hot, moist autumn. Of course the later in the season infection takes place the less likely is the head to be spoiled.

EFFECT OF WEATHER CONDITIONS.

The most favorable temperature for the growth of this germ, as determined by laboratory experiments, is that of our hot summer weather (80° to 90° F., or possibly a little higher), and field observations seem to show that this kind of weather is very favorable to the rapid spread of the disease whereas cool weather appears to check it. Warm days, cool nights, and frequent showers offer the most suitable conditions for rapid infection by way of the water pores. Dry weather, dry soil, warm nights, and temperate days furnish the conditions under which infection by way of the water pores is least likely to take place. A striking example of the effect of dry soil was seen in Wisconsin. A field of some acres was planted to cabbages in 1896 and again in 1897. The greater part of the crop of 1896 rotted on the ground, and, in August, 13 per cent of the crop of 1897 was diseased, except on one corner of the field (about one-fourth acre), where the soil was of a slightly different texture, looser, and drier, as determined by stirring with the foot and by the appearance of the cabbages, which were one-third smaller and were suffering somewhat from lack of water, no rain having fallen for some weeks. Here there were scarcely any infections. On the rest of the field the cabbages were large and the water-pore infections were numerous. The only inference possible was that the germs could not gain entrance into these plants simply because no water in the form of drops had been extruded from their water pores.

ROTATION OF CROPS AS A REMEDY.

In New York fields were seen where cabbages had been grown uninterruptedly for from five to eleven years, and the plants in some of these fields were badly diseased. It goes without saying that such methods of agriculture are usually not to be recommended, rotation of crops being, for many reasons, a cardinal principle of good farming. If, however, on account of cost of preparation of soil or of the lack of other suitable fields, it is necessary to plant on the same ground year after year, then it becomes of the utmost importance to avoid the first introduction of the germ.

The planting of other crops for a long series of years seems to be the only satisfactory way of getting rid of the disease when it has once become serious. Fields that have shown even a little of the disease should not be planted to cabbages or other cruciferous plants for several years. As far as possible, the cabbages should be set each year on ground which has been for some seasons in sod or else cultivated to crops not subject to this disease. It seems likely that the serious loss to cabbage growers from this cause might be almost wholly avoided by following this simple rule, especially if growers would also put in prac-

tice the directions given below respecting the seed bed. How long the germs of this disease will live in a soil is uncertain, but probably, if the conditions are favorable, quite a good many years, so that cabbage growers, if they wish to continue the business successfully, ought to take the utmost precaution to keep their fields from becoming infected.

REMOVAL OF AFFECTED LEAVES.

Pulling off the leaves in the early stages of the disease—that is, while the malady is confined to the margins of the leaf—might be tried. If this were done thoroughly in an early stage of the rot, it seems likely that it would be of some help in combating the disease when already present. This method was tried by the writer in August, 1897, on about four hundred plants, with very satisfactory results, four-fifths of the heads being free from disease when harvested in November. The one-fifth may have been diseased in the stem at the time the leaves were broken off, or may have subsequently contracted the disease through other leaves. The water-pore infections are so conspicuous on the cabbage that intelligent growers will have no trouble in applying this method of treatment, nor, after a little experience, will they be in much doubt as to what plants should be treated in this way and what ones should be removed bodily owing to the fact that the germs have already entered the stem. Of course after the germs have once entered the stem they are beyond reach.

DESTRUCTION OF CABBAGE-FEEDING INSECTS.

The destruction of insects, particularly the harlequin cabbage bug and the larvæ of the cabbage butterfly, should also be thought of in connection with the prevention of this disease. The bites of insects certainly can and do introduce the disease in a certain proportion of the cases, and it seems likely to the writer, as already stated, that the germs are carried from one part of the plant to another and many indirect inoculations brought about in this way—i. e., as the result of germs lodged over the water pores. The importance of this will be more apparent if we remember that the infection of a single leaf, especially when the season is well advanced, seldom destroys the head, whereas the head is pretty certain to be spoiled if many leaves are infected. When there are no insect carriers the danger to healthy fields from proximity to diseased fields appears to be very slight. (See account of field of W. S. Pratt, p. 19.)

THE SEED BED.

It is very important to watch the seed bed and to set out only healthy seedlings. The observations of the writer the past summer have shown beyond much doubt that the disease is often transmitted from the seed bed to the field. The disease was unquestionably introduced in this manner into several of the worst affected fields seen this year.

An observation made in northern Ohio and reported to the writer by

the grower is very interesting in this connection. In 1896 the disease was prevalent in certain fields on this man's farm, and a large number of cabbages which had been stored in a pit rotted in the ground. About one-third of the seed bed for 1897 was planted over the pit, i. e., on soil which contained the refuse of this rotted cabbage, the rest of the bed being on land adjoining this, but free from the refuse of the cabbage heap. The cabbages grown on the soil containing the refuse came up sooner than on the rest of the bed, but many of them, to quote the language of the grower, "were brown on the stem, as if stung, and on breaking them open a black spot was seen." The first fields were set from this part of the bed. Later the cabbages from the rest of the bed were used. The disease in 1897 was severe and was confined almost exclusively to the cabbages which were first taken from the bed, i. e., to those taken from that part of the bed which received the rotten cabbages.

In September a great many stunted and diseased plants were observed on a seed bed in Ohio, and there was clear evidence from an examination of them that the plants had been diseased for many months—probably from springtime. Unfortunately, only a few plants had been set from this bed and another bed from which most of the field was set had been plowed under. There was much disease in the fields, and possibly the other bed had also furnished diseased plants. About two-thirds of a field of 11 acres at Clyde was diseased, one-third very badly. Cases appeared in this field as early as the second week after it was set out, so that here also the disease may have been introduced from a seed bed. The seed bed had been plowed under. All that could be learned definitely was that this seed bed had been on the same piece of ground for some years and that the field had been planted to cabbage seven years in succession.

SOME INSTRUCTIVE COMPARISONS.

The most striking case of all was observed near Racine. A small field was in cabbages in 1896 and nearly all of them were affected by the disease, so that the owner obtained only a few wagonloads of cabbages from it. Last spring a seed bed was made on one end of this field. In August, when it was examined, the bed was covered with tall weeds, but underneath the weeds there still remained several thousand small cabbages. There was not much surface indication of the disease in these cabbages, growth being nearly at a standstill, but on pulling and carefully examining them 20 per cent were found to be affected, and the evidence was conclusive that they had been suffering from this disease for some months, probably from early summer.[1] Two

[1] The plants were similar in appearance to greenhouse plants inoculated in November and December, 1896, and still living in July, 1897, i. e., to plants which, in addition to being inoculated, were stunted by being retained in small pots. Some of these plants were alive and showed fresh symptoms of disease thirteen months after inoculation and more than a year after the first symptoms appeared.

fields were set from this bed on farms about a mile apart and the plants in both were badly affected, the disease being further advanced in them than in any other fields seen during the whole season, with the exception of one field in Ohio and one in Michigan.

One of the fields was carefully examined by rows and all the affected plants counted. About 20 per cent of the heads were found to be badly diseased, i. e., the same proportion as on the seed bed, and a large number of additional heads, i. e., 38 per cent, showed the rot to a less extent. In other words, considerably over one-half of all the plants were diseased, not a single row in the whole field being exempt. An adjoining field, on similar land and separated only by a wire fence, appeared from a distance to be entirely free from the disease, and a subsequent careful inspection of all the plants in the field brought to light only 19 badly rotted heads, i. e., about 1 head in 1,200. This field was planted with cabbages out of a healthy seed bed.

Both fields were on level, fertile land, not previously planted to cabbages, except the middle portion of the healthy field, and the one which rotted so badly seemed to be in the best possible condition to yield a healthy crop, i. e., it had been in sod many years. Instead, however, of yielding such a crop, it gave the worst possible result; and this, beyond any question, was due to the fact that infected cabbages were transplanted into it from the seed bed. The writer came to this conclusion from a study of the seed bed and of the field, and his views were subsequently substantiated by the tenant himself, who admitted having seen the black-stem disease in many of the seedlings when he planted them. He said, however, that he supposed the cabbage rot was due to a worm, and thought nothing about this particular appearance. These two fields were in such striking contrast that all the cabbages in them were examined by double rows, the diseased plants being classified into two groups, according to severity of symptoms.

The location and surroundings of these two fields are given in the following diagram:

1. **Field of Elvin Andre.**—Examined September 5–7, 1897; 23,040 plants, besides quite a good many missing; variety, Holland.

Group 1, 4,538 plants, badly diseased; cabbages which were rotted in the stump or the head or so badly dwarfed that no head had formed. The plants were probably infected prior to the date of setting out, which was about June 25; in other words, they were already diseased when transplanted from the seed bed.

Group 2, 8,800 plants, not so badly diseased, but many of them likely to be spoiled before harvest (about October 15). These plants were not dwarfed or rotten. So far as examined, they were not yet affected in the stump or center of the head, but showed numerous rapidly spreading leaf infections. There were several hundred thousand separate infections on these plants, mostly through the water pores, and all may be safely assumed to have taken place after the plants were set

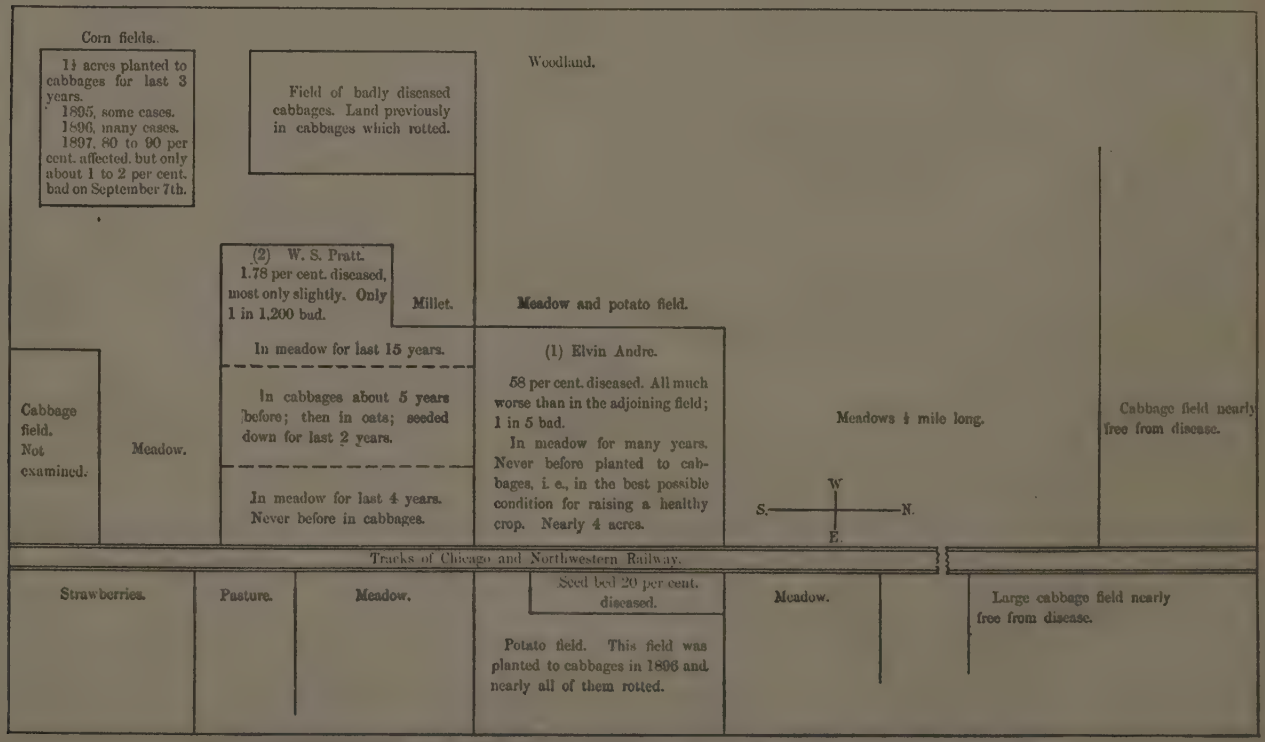
Corn fields.
1½ acres planted to cabbages for last 3 years.
1895, some cases.
1896, many cases.
1897, 80 to 90 per cent. affected, but only about 1 to 2 per cent. bad on September 7th.
Field of badly diseased cabbages. Land previously in cabbages which rotted.
Woodland.
(2) W. S. Pratt.
1.78 per cent. diseased, most only slightly. Only 1 in 1,200 bad.
Millet.
Meadow and potato field.
In meadow for last 15 years.
(1) Elvin Andre.
58 per cent. diseased. All much worse than in the adjoining field; 1 in 5 bad.
In meadow for many years. Never before planted to cabbages, i. e., in the best possible condition for raising a healthy crop. Nearly 4 acres.
Cabbage field. Not examined.
Meadow.
In cabbages about 5 years before; then in oats; seeded down for last 2 years.
In meadow for last 4 years. Never before in cabbages.
Meadows ¼ mile long.
Cabbage field nearly free from disease.
W
S.
N.
E.
Tracks of Chicago and Northwestern Railway.
Strawberries.
Pasture.
Meadow.
Seed bed 20 per cent. diseased.
Potato field. This field was planted to cabbages in 1896 and nearly all of them rotted.
Meadow.
Large cabbage field nearly free from disease.

FIG. 1.—Diagram showing location of the cabbage fields which are described more in detail on the accompanying pages.

out. They are believed to have contracted the disease from the plants of group 1. The number of separate inoculations was enormous. For example, on the leaves of a single plant 170 distinct water-pore infections were counted, and many of these were spreading rapidly; but the bases of all the leaves were still healthy, the stump was sound and free from any black stain, and the head was 6 inches in diameter, symmetrical, hard, and sound. Another month would have seen an entire change in the condition of plants such as this.

If these deductions are correct, Mr. Andre might have had a field entirely free from disease but for the misfortune of planting his seed bed in the wrong place, i. e., on infected land. The soil is now thoroughly infested with a bad weed, to wit, the microscopic germ of the black rot, and is spoiled for cabbage growing indefinitely.

This field developed the disease so early in the season and so extensively that it was abandoned in midsummer and allowed to grow up to charlock; in fact, the mustard was what first drew my attention to the field. At least 100,000 of these mustard plants had also contracted the disease, as already mentioned.

2. Field of W. S. Pratt.—Examined September 7 and 8, 1897; 23,040 plants, very few missing; variety Holland. The field contained about 30,000 plants. Those on the extreme west end were examined, but not counted by rows, and are not here included.

Group 1, 19 plants badly diseased, i. e., like those in group 1 of Mr. Andre's field.

Group 2, 383 plants slightly attacked, i. e., 1 to 6 or more, mostly marginal leaf infections, but almost all of them very slight, or, in other words, quite recent; on an average not one-fiftieth as many separate infections per plant as in group 2 of Mr. Andre's field. All the affected leaves were broken off when the plants were examined, and the progress of the disease was checked.

Most of the plants falling into this second group were in the middle of the field. Thus one-third of the field yielded three-fourths of the cases and at least 90 per cent of the total number of leaf infections. For a time the writer was at a loss to account for this peculiar distribution of the disease, but on looking over the memoranda given him by the owner of the field he was surprised to find that this excess of cases was in that part of the field which had been planted to cabbages five years before. Possibly among these cabbages there were some diseased plants, and the germs may have persisted in the soil ever since, or may have been tided over by means of the charlock. Where one plant was infected several others in the immediate vicinity were apt to be, as if the contagium were of very local origin. This hypothesis is the only one I can think of which sufficiently explains the observed phenomena, and this does fully explain it.

Finally, if these inferences are well founded, Mr. Pratt's field would have been a duplicate of Mr. Andre's, if he had obtained his seedlings from the same seed bed.

The cabbages in Mr. Andre's field were rotted up to the line fence. The outer ten rows yielded 391 badly diseased plants, with 249 recent infections; the next ten rows 411 badly diseased plants, with 361 recent cases, and so on, but this fact exerted no appreciable influence on the adjoining rows of Mr. Pratt's field. Neither was there any excess of cases on the back end of Mr. Pratt's field, i. e., the part nearest the diseased fields to the west and southwest, although these were only a few rods distant and were badly diseased in 1896 as well as this year. There were very few mustard plants in Mr. Pratt's field, but among these few some showed marginal leaf infections.

PROMPT MARKETING.

Where the disease has made serious inroads in fields of cabbages it would seem to be absolutely essential to market those not badly affected—that is, those only browned a little in the stems—as soon as possible in the fall. The heads of many at this time are not at all injured for use. Where cabbages of this sort are stored the brown rot is likely to continue through the winter, and other organisms which follow in the wake of this parasite are also likely to multiply, causing soft rots.

STORAGE.

If it is impossible to sell the cabbages to advantage in the fall and storage becomes a necessity, then those heads which are to be stored should be inspected with unusual care and any which show the least traces of blackening in the stems should be rejected, or at least stored by themselves in the lowest, coolest part of the house.

As an additional safeguard the houses ought to be so constructed that they can be uniformly warmed and ventilated. Storehouse men have told me that the chief loss from rot during the winter is in the upper parts of these houses. This is attributable, undoubtedly, to the fact that the warm air rises to the roof and there gives a temperature high enough for the continued growth of the organisms which destroy the cabbages. The temperature in the cabbage storehouses ought to be as uniform as possible and as near the freezing point as is consistent with the proper preservation of the cabbage. It is not enough to know the temperature in the lower part of the house, but that in the upper parts must also be known and controlled.

NO DANGER FROM EATING AFFECTED CABBAGES.

The black or brown stain in the veins of the leaves is so distinct that no one is likely to buy or eat badly affected heads, and it is believed that no danger is likely to ensue from the consumption of slightly affected ones, because the germ does not grow well at blood heat and is easily destroyed by cooking.

No inoculations have been made to determine whether it is pathogenic to animals.

SYNOPSIS OF RULES FOR PREVENTION.

The field observations described above, taken in connection with the characters of the disease as previously worked out, lead the writer to believe that this trouble may be successfully combated by means of what he has frequently designated as field hygiene. If he were asked to give in concise terms a few rules for avoiding this disease they would be about as follows:

1. Plant the cabbage seed on land where this disease has never appeared. When the plants are ready to set out inspect the seed bed very carefully, and if any cases of the disease are found reject all the plants and set from some other bed. One can not afford to run any risk of infecting his land by the use of seedlings from suspicious beds. It would be better to plant some other crop than to take this risk. A good practice is to strew the land to be used for seed bed with straw or dry brush and burn it over before plowing. The seed bed should be made in a different place each year.

2. Set the plants on land which has not been in cabbages or other cruciferous plants for some time. If it is impossible to avoid following cabbages by cabbages, at least take the precaution to plant only on land which has never suffered from this disease. To follow any other course is simply to invite the trouble. The practice of planting cabbages after cabbages for a long series of years also invites other parasites, and must as a rule be considered very bad economy.

3. As a matter of precaution avoid the use of stable manures, since these may possibly serve as a means of carrying the disease into uninfected fields, that is, through cabbage refuse fed to animals or thrown into the barnyard or onto manure piles. As far as possible make use of commercial fertilizers in place of barnyard manures, both in the seed bed and in the field, at least until it shall have been shown conclusively that there is no danger in the manure pile. Too much stress can not be laid on the necessity of keeping the germs out of the soil, and consequently on the avoidance of practices which, if not absolutely proved to be dangerous, are at least questionable.

4. Do not turn animals into diseased fields and then allow them to wander over other parts of the farm. Cattle or other stock should not be allowed to roam in cabbage fields where this disease prevails.

5. All farm tools used on infected land should be scoured bright before using on uninfected land. The transfer of soil from infected to healthy fields ought in all cases to be reduced to a minimum.

6. Keep up a constant warfare against insect enemies, especially the cabbage butterfly and the harlequin bug.

7. As a palliative remove badly affected plants from the field as fast as they appear. In early stages of the disease—i. e., while it is still confined to the margins of the leaves and has not yet entered the head or stump—go over the fields systematically about once every ten days

and break off and remove all the affected leaves. Do not throw this refuse into cultivated fields, or into ditches from which it can be washed to other fields, or on roadways to be tracked about. It should be burned or put into a deep pit in some fence corner or other out-of-the-way place.

8. Weeds which harbor the disease, especially the wild mustards, must be destroyed systematically.

9. Store cabbages from diseased fields only when it is impossible to sell them in the fall, and in such cases take particular care to reject all heads showing any trace of black in the stump and to keep all parts of the houses below 40° F. If any affected heads are stored they should be put by themselves in the lowest, coolest part of the house.

FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C.

[Only the bulletins named below are available for distribution.]

No. 15. Some Destructive Potato Diseases: What They Are and How to Prevent Them. Pp. 8.
No. 16. Leguminous Plants for Green Manuring and for Feeding. Pp. 24.
No. 18. Forage Plants for the South. Pp. 30.
No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
No. 20. Washed Soils: How to Prevent and Reclaim Them. Pp. 22.
No. 21. Barnyard Manure. Pp. 32.
No. 22. Feeding Farm Animals. Pp. 32.
No. 23. Foods: Nutritive Value and Cost. Pp. 32.
No. 24. Hog Cholera and Swine Plague. Pp. 16.
No. 25. Peanuts: Culture and Uses. Pp. 24.
No. 26. Sweet Potatoes: Culture and Uses. Pp. 30.
No. 27. Flax for Seed and Fiber. Pp. 16.
No. 28. Weeds; and How to Kill Them. Pp. 30.
No. 29. Souring of Milk and Other Changes in Milk Products. Pp. 23.
No. 30. Grape Diseases on the Pacific Coast. Pp. 16.
No. 31. Alfalfa, or Lucern. Pp. 23.
No. 32. Silos and Silage. Pp. 31.
No. 33. Peach Growing for Market. Pp. 24.
No. 34. Meats: Composition and Cooking. Pp. 29.
No. 35. Potato Culture. Pp. 23.
No. 36. Cotton Seed and Its Products. Pp. 16.
No. 37. Kafir Corn: Characteristics, Culture, and Uses. Pp. 12.
No. 38. Spraying for Fruit Diseases. Pp. 12.
No. 39. Onion Culture. Pp. 31.
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No. 42. Facts about Milk. Pp. 29.
No. 43. Sewage Disposal on the Farm. Pp. 22.
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No. 51. Standard Varieties of Chickens. Pp. 48.
No. 52. The Sugar Beet. Pp. 48.
No. 53. How to Grow Mushrooms. Pp. 20.
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No. 55. The Dairy Herd: Its Formation and Management. Pp. 24.
No. 56. Experiment Station Work—I. Pp. 30.
No. 57. Butter Making on the Farm. Pp. 15.
No. 58. The Soy Bean as a Forage Crop. Pp. 24.
No. 59. Bee Keeping. Pp. 32.
No. 60. Methods of Curing Tobacco. Pp. 16.
No. 61. Asparagus Culture. Pp. 40.
No. 62. Marketing Farm Produce. Pp. 28.
No. 63. Care of Milk on the Farm. Pp. 40.
No. 64. Ducks and Geese. Pp. 48.
No. 65. Experiment Station Work—II. Pp. 32.
No. 66. Meadows and Pastures. Pp. 24.
No. 67. Forestry for Farmers. Pp. 48.

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